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(54) Title: LIGHT-EMITTING DEVICES

(57) Abstract: A light-emitting device comprising: a first electroluminescent element for emitting light of a first colour when energised; and a second electroluminescent element for emitting light of a second colour when energised, the first electroluminescent element having an active lifetime which is greater than that of the second electroluminescent element; characterised in that the second element is configured to operate at a lower brightness than the first element.

For two-letter codes and other abbreviations, refer to the "Guid-ance Notes on Codes and Abbreviations" appearing at the begin-ning of each regular issue of the PCT Gazette.

5   TITLE: LIGHT-EMITTING DEVICES

10   DESCRIPTION

15   The present invention relates to a light-emitting
device, particularly an electroluminescent device and
displays incorporating such devices. The
electroluminescence for the electroluminescent device may
be provided by means of an organic light-emissive material
20 (see for example International Publication WO90/13148 which
describes electroluminescent semi-conductive conjugated
polymers, such as PPV).

       By way of background, Figure 1 shows the typical
cross-sectional structure of an organic light-emissive
25 device. The device is fabricated on a substrate (1) coated
with a transparent first electrode (2) such as indium-tin-
oxide. The coated substrate is overcoated with at least
one layer of a thin film of an electroluminescent organic

material (3) and a final layer forming a second electrode (4) which is typically of metal. By using a transparent substrate (e.g. of glass or plastics material), light generated in the film (3) is able to leave the device by 5 passing through the first electrode (2).

The performance of electroluminescent devices has advanced rapidly over the past few years. Due to their high efficiencies, the devices show potential for a wide range of display applications, from simple backlights to 10 graphic displays, such as television screens, computer monitors and palm-top devices which may consist of several million pixels. However, there is considerable variation in the active lifetimes of red, green and blue organic electroluminescent systems, including polymer systems. For 15 the purposes of the present specification, the active lifetime of an electroluminescent element is defined as the maximum time for which the element is able to produce at least a display-monitor level of brightness (for example, set at $100cd/m^2$) when operating under a given drive scheme. 20 For example, an electroluminescent device with a red light emitting polymer may have an active life of 30,000 hours at 5 volts, whereas a device with a blue light-emitting polymer may have an active life of only 1500 hours at the same voltage (see table 1).

25   The disparity in active lifetimes of organic light-emissive materials is significant because one factor in determining the useful life or service life of a graphic display incorporating such materials is governed by the

shortest of the active lifetimes of the different polymers employed. (Another factor concerns decay rates causing colour shift, which can reduce overall colour purity, i.e. 'white' becomes 'off-white', and possibly also produce non-

5 uniformity in the display). Accordingly, attempts have been made to improve the service life of graphic displays. For example, research has been conducted into upgrading the active lifetime of the 'weak link' in such displays; namely, the relatively short-lived blue light-emitting

10 polymers. Also, systems have been devised to compensate the device driving current - either by using a sensing mechanism or by predicting the rate of performance decay in complex drive compensation electronics - to maintain optimal performance with time. However, compensation

15 mechanisms require complex and expensive circuitry which may also impose restrictions on the available aperture ratio.

An object of the present invention is to improve the service life of graphic displays incorporating organic

20 light-emissive materials.

In accordance with a first aspect of the present invention, there is provided a light-emitting device comprising: a first electroluminescent element for emitting light of a first colour when energised; and a second

25 electroluminescent element for emitting light of a second colour when energised, the first electroluminescent element having an active lifetime which is greater than that of the second electroluminescent element, characterised in that

the second element is configured to operate at a lower
brightness than the first element.

The brightness or luminescence of light emitted by an
object may be measured in candela per square meter, and is
5 a measure of the amount of light (number of photons)
emitted per second per unit solid angle per unit area, as
corrected for the sensitivity of the eye. The
instantaneous brightness may vary - intentionally or
otherwise - from one moment to another. When considering
10 light-emitting devices for use in graphic displays,
variations in instantaneous brightness may occur too
rapidly to be detected by the human eye. Accordingly, the
"brightness" which is of interest to the present invention
is time-averaged to the extent necessary to smooth out
15 localised or high speed variations in instantaneous
brightness.

The first and second electroluminescent elements may
comprise organic light emissive materials, and may be
polymeric materials such as those discussed in WO90/13148
20 or WO92/03490.

The present applicant has appreciated the implication
of the correlation between brightness and service life of
devices employing organic light-emissive materials. The
correlation is illustrated schematically in Figure 2 for
25 two electroluminescent elements employing different organic
light-emissive materials, for example a red light emitter
(R) and a blue light emitter (B) which have different
active lifetimes. The correlation for each may be

summarised as a relatively high brightness being indicative
of a relatively short, service life and *vice versa*. If both
organic light-emissive materials are operated continuously
at the same level of brightness, the material with the
5 shortest active lifetime will fail (i.e. reach the end of
its active life) first (in the example, the blue will fail
before the red) and the device will be judged to have
failed prematurely at t_1. However if the material with the
shortest active lifetime is operated continuously at a
10 lower level of brightness than the other material, the
service life of the device will be extended to t_2.

The ratio between the brightness (B_1) of the first
electroluminescent element and the brightness (B_2) of the
second electroluminescent element may be substantially
15 equal to the ratio between the active lifetime (τ_1) of the
first element and the active lifetime (τ_2) of the second
element (i.e. $B_1/B_2 = \tau_1/\tau_2$). Suppose, for example, that
there is an order of magnitude difference in the active
lifetime of the two elements (e.g. active lifetime of the
20 first element is 30,000 hrs and the active lifetime of the
second element is 3,000 hrs). If the two elements are to
fail at substantially the same time, it may be necessary to
operate the second element at one tenth of the brightness
of the first element.

25 There may be another advantage to operating the second
element (shorter active lifetime) at a lower brightness
than the first element. When operated continuously, the

amount of light emitted per unit time by the first and second elements may decrease or decay with time, with the rate of decay perhaps being greater for the second element. Thus, the perceived colour of the light-emitting device

5 with both elements energised will drift with time because the contribution by the second element to the overall light output slowly decreases. However, by operating the second element at a lower brightness than the second element may have the effect of retarding the rate of decay in the

10 amount of light emitted per unit time. In other words, the rates of decay in the amount of light emitted per unit time by the first and second elements may become more even. Hence, the problem of perceived colour drift with time may be alleviated.

15   The first and second electroluminescent elements may be energised by a common potential difference, for example by using a common cathode. The correlation between brightness (or luminance in cd/m^2) and voltage is illustrated schematically in Figure 3 for two

20 electroluminescent elements employing different materials, for example a red light emitter (RED) and a blue light emitter (BLUE) which have different driving voltage characteristics. In fact, the red light emitter (RED) has a lower driving voltage characteristic than the blue light

25 emitter (BLUE). Thus, by driving the two elements at a common potential (V_1), the red light emitter will be operating at a higher brightness than the blue light emitter ($B_1 > B_2$). Accordingly, the goal of extending the

service life of the device is attainable by operating at a common potential.

In an alternative embodiment, the first and second elements may be energised by different potentials. The second element may be energised at a higher potential than the first element. Referring to Figure 3, driving the blue light emitter (BLUE) at V_2 will yield a brightness B_3 which is greater than B_2. Of course, if performance characteristics were reversed in Figure 3 or the RED and BLUE curves cross over in the drive potential regime, the first element may be energised at a higher potential than the second element.

The second element may be energised in pulses. Pulsing has the effect of lowering the time-averaged brightness as compared to operating continuously, e.g. at a constant potential. Thus, even though the blue light emitter (BLUE) is operating at a higher potential than before ($V_2>V_1$), the service life of the device may still be greater than t_1 because the emitter is only energised for a fraction (e.g. less than $^1/_{10}$) of the overall time. The second element may be pulsed at a frequency in excess of 50 Hz, and perhaps at 100 Hz. Although lower frequencies would also have the effect of lowering the time-averaged brightness, it may be desirable in some applications to pulse at a rate which is faster than the eye response function. Each pulse may last for perhaps 200 microseconds, with perhaps 20 milliseconds between pulses.

The first and second elements may be pulsed, with the

time-averaged brightness for the first element being
greater than that for the second element. Thus, if the
first and second elements are operating at a common
potential, the first element may be energised for longer

5 periods that the second element. This may be achieved by
pulsing the first element more frequently than the second
element or by increasing the duration of each pulse (pulse
width) for the first element relative to that for the
second element. Pulsing of both elements may be useful for

10 light-emitting devices incorporated in passive matrix-
driven displays.

The second element may be adapted to emit light over a
larger area than the first element. The difference in
light-emitting areas may be such that the total light

15 output from the first element is substantially equal to
that from the second element over a comparable time frame.
For example, if there is no difference in duration of
activation, the ratio between the light-emitting area (A_1)
of the first element and the light-emitting area (A_2) of the

20 second element may be substantially equal to the ratio
between the brightness (B_2) of the second element and the
brightness (B_1) of the first element (i.e. $A_1/A_2 \approx B_2/B_1$). By
operating the second element at a lower time-averaged
brightness than the first element, the amount of light

25 observed by an observer from the elements will differ if
the elements are of equal size (assuming the duration of
activation is equal). This is because with normal eye

constraints (e.g. sampling and resolution factors) the amount of light received from an element is related to the product of the time-averaged brightness and the area over which light is emitted. However, by increasing the size of 5 the second element relative to the first element, such a difference may be offset somewhat or even totally compensated.

The brightnesses of the first and second electroluminescent elements may be chosen such that the 10 half-lives of the first and second electroluminescent elements are substantially equal.

The choice of driving conditions for the two electroluminescent elements may be governed by material properties. Figure 4 shows a plot of efficiency against 15 current density for red and blue light-emissive polymers in the first and second electroluminescent elements, respectively. If the device is to operate at optimum efficiency, the first electroluminescent element will need to operate at a first current density σ_1, whilst the second 20 electroluminescent element will need to operate at a second current density σ_2, with $\sigma_1 > \sigma_2$. The current density σ_2 may, for example, be achieved by operating the second element at a higher potential than the first element, and achieve a lower brightness by pulsing the second element.

25 The device may further comprise a third electroluminescent element for emitting light of a third colour when energised, the third electroluminescent element

having an active lifetime in between that of the first and
second electroluminescent elements. All elements may
comprise organic light-emissive materials, and may be
polymeric materials such as those disclosed in WO90/13148
5 or WO92/03490. All elements may be energised by a common
potential difference, or at different potentials, perhaps
with the second element at the highest potential and the
first element at the lowest, and perhaps with the second
element being pulsed.

10   The third element may be adapted to emit light over an
area which is greater than the first element but smaller
than the second element. The reason for doing this is
again to achieve the desired total light output per unit
time. The effect of doing this is the same as increasing
15 the service life of the second element at the expense of
the first element. This is because in practice, when
dealing with a finite substrate, the light-emitting area of
the third element will be normalised and the areas of the
first and second elements will be relatively smaller and
20 larger respectively.

        There is also provided a graphic display incorporating
a light-emitting device according to the first aspect of
the invention, wherein each electroluminescent element in
the device corresponds to a pixel for displaying graphic
25 information.

        In accordance with a second aspect of the present
invention, there is provided a light-emitting device
comprising: a first electroluminescent element for emitting

light of a first brightness (B_1) when energised by a predetermined potential; and a second electroluminescent element for emitting light of a second brightness (B_2) when energised by the predetermined potential, the second

5 brightness being less than the first brightness; characterised by means for energising the first and second electroluminescent elements at the predetermined potential, and in that the second electroluminescent element has a larger light-emitting area than the first

10 electroluminescent element.

The second aspect of the present invention provides for increasing the light-emitting area of the element with the lowest brightness relative to that of the element with the highest brightness, with a view to reducing the

15 difference in the total light emitted by the elements in unit time. In the absence of such an areal compensation, the brightest element (i.e. the first electroluminescent element) will emit more light than the other element when operating at a common potential.

20   The first or second electroluminescent element may comprise an organic light-emissive material. The organic light-emissive material may be polymeric.

The energising means may comprise at least one electrode common to both electroluminescent elements. For

25 example, the energising means may comprise an anode and a cathode, each common to both electroluminescent elements.

The total light emitted by the first electroluminescent element may be substantially equal to

the total light emitted by the second electroluminescent
element in any given time interval when both
electroluminescent elements are energised. The ratio of
the first brightness (B_1) to the second brightness (B_2) may

5 be substantially equal to the ratio of the light-emitting
area of the second electroluminescent element (A_2) to the
light-emitting area of the first electroluminescent element
(A_1), i.e. $B_1/B_2 \approx A_2/A_1$.

The first and second electroluminescent elements may

10 emit light of first and second colours respectively when
energised, the first and second colours being selected from
the group consisting of red, green and blue.

The light-emitting device may further comprise: a
third electroluminescent element for emitting light of a

15 third brightness when energised by the predetermined
potential, the third brightness being in between that of
the first and second brightness; and means for energising
the third electroluminescent element at the predetermined
potential. The third electroluminescent element may have a

20 light-emitting area greater than that of the first element
and less than that of the second element.

There may be provided a graphic display comprising a
light-emitting device according to the second aspect of the
invention, wherein each electroluminescent element

25 corresponds to a pixel for displaying graphic information.

In accordance with a third aspect of the invention,
there is provided a light-emitting device comprising: a

first electroluminescent element for emitting light of a first colour when energized; and a second electroluminescent element for emitting light of a second colour when energized, the first electroluminescent element

5 emitting light at a lower luminance than that of the second electroluminescent element when each is energized with optimal efficiency; characterized in that the first and second electroluminescent elements are configured to operate at the same perceived brightness when both

10 electroluminescent elements are energized with optimal efficiency.

The third aspect of the invention provides for operating light emitting elements - having different luminance versus efficiency characteristics - at optimal

15 efficiency whilst at the same time achieving uniformity in the light output from each element. Such a light emitting device may be valuable where lifetime is not an issue, which may well be the case in certain "throwaway" applications.

20 The first or second electroluminescent elements may comprise an organic light-emissive material. The organic light-emissive material may be polymeric. The first and second electroluminescent elements may be energized by a common potential.

25 The first and second electroluminescent elements may be energized by different potentials, and the second electroluminescent element may be energized at a higher potential than the first electroluminescent element. The

energizing potential applied to one or both of the electroluminescent elements may be pulsed, with the first electroluminescent element perhaps being energized for longer periods than the second electroluminescent element.

5 For example, the first electroluminescent element may be pulsed more frequently or with a greater pulse width than the second electroluminescent element.

The first electroluminescent element may be configured to emit light over a larger area than the second

10 electroluminescent element. The ratio between the light emitting areas of the first and second electroluminescent elements (A_1 and A_2) may be substantially equal to the ratio between the luminances of the second and first electroluminescent elements (L_2 and L_1) respectively when

15 energized at optimal efficiency, i.e., A_1/A_2 L_2/L_1.

The first and second colours of light emitted from the electroluminescent elements are selected from the group consisting of red, green and blue. The device may further comprise a third electroluminescent element for emitting

20 light of a third colour when energized, the third electroluminescent element emitting light at a luminance in between that of the first and second electroluminescent elements when energized with optimal efficiency.

There may also be provided a graphic display

25 comprising a light-emitting device according to the third aspect of the invention, wherein each electroluminescent element corresponds to a pixel for displaying graphic information.

In accordance with a fourth aspect of the invention, there is provided a, light-emitting device comprising: a first electroluminescent element for emitting light of a first colour when energized; and a second

5 electroluminescent element for emitting light of a second colour when energized, the first electroluminescent element having a half-life which is greater than that of the second electroluminescent element when each is energized with optimal efficiency; characterized in that the second

10 electroluminescent element is configured to operate at a lower brightness than the first electroluminescent element when both are energized with optimal efficiency.

The third aspect of the invention provides for operating light-emitting elements - having different half-

15 life versus efficiency characteristics - at optimal efficiency and in such a way that the service life of the device is increased.

The first or second electroluminescent elements may comprise an organic light-emissive material. The organic

20 light-emissive material may be polymeric. The first and second electroluminescent elements may be energized by a common potential.

The first and second electroluminescent elements may be energized by different potentials, and the second

25 electroluminescent element may be energized at a higher potential than the first electroluminescent element. The energizing potential applied to one or both of the electroluminescent elements may be pulsed with the first

electroluminescent element perhaps being energized for longer periods than the second electroluminescent element. For example, the second electroluminescent element may only be energized for short periods whilst the first

5 electroluminescent element is operated continuously. The ratio between the energization times for the first and second electroluminescent elements (t_1 and t_2) may be substantially equal to the ratio between the half-lives of the second and first electroluminescent elements (T_2 and T_1)

10 respectively when energized at optimal efficiency, i.e. $t_1/t_2 \approx T_2/T_1$.

The first electroluminescent element may be configured to emit light over a larger area than the second electroluminescent element. The ratio between the light

15 emitting areas of the first and second electroluminescent elements (A_1 and A_2) may be substantially equal to the ratio between the brightnesses of the second and first electroluminescent elements (B_2 and B_1) respectively when energized at optimal efficiency, i.e., A_1/A_2 B_2/B_1.

20   The first and second colours of light emitted from the electroluminescent elements are selected from the group consisting of red, green and blue. The device may further comprise a third electroluminescent element for emitting light of a third colour when energized, the third

25 electroluminescent element emitting light at a luminance in between that of the first and second electroluminescent elements when energized with optimal efficiency.

There may also be provided a graphic display comprising a light-emitting device according to the third aspect of the invention, wherein each electroluminescent element corresponds to a pixel for displaying graphic
5 information.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic illustration of an organic
10 light-emissive device known in the art;

Figure 2 is a schematic illustration showing how brightness affects the service life of the device of Figure 1 operating under constant drive conditions;

Figure 3 is a schematic plot of brightness against
15 voltage for two different electroluminescent elements;

Figure 4 is a schematic plot of efficiency against current density for the first and second elements;

Figure 5 is a graph showing pixel half-life as a function of pixel luminance for the colours red, green and
20 blue;

Figure 6 is a graph showing luminance versus voltage curves for red, green and blue light emitting polymer pixels;

Figure 7 is a graph showing efficiency versus
25 luminance for the colours red, green and blue;

Figure 8 is a graph showing half-life versus pixel voltage for the colours red, green and blue.

Figure 9 is a graph showing half-life versus

efficiency for the colours red, green and blue.

Figure 10 is a schematic illustration of a graphic display embodying the present invention;

Figure 11 shows pulse driving for "red" and "green"
5 elements in figure 10;

Figure 12 shows schematically how different pixel areas can be achieved; and

Figure 13 shows a possible driving scheme providing different energy pulse widths to each pixel colour in
10 figure 12.

The perceived brightness of a display depends on the following parameters:

$$Luminance_{perceived} = Luminance_{pixel} . Area\_ratio_{pixel} . Pulse\_width\_ratio$$

In this equation the $Luminance_{perceived}$ is the luminance seen
15 by the eye assuming that the pixel size is below the eye resolution limit' and the pulse repetition rate is faster than the eye response. The luminance of a pixel depends on:

$$Luminance_{pixel} = f[(Efficiency_{pixel} \ (time\_total, \ V_{pixel} \ or \ I_{pixel})]$$

20   Accordingly, the perceived luminance depends on:

1.   Pixel area ratios

2.   Pixel pulse width ratio

3.   Pixel efficiency

4.   Pixel half-life, or how the efficiency is
25   changing with time

5.   The current or voltage supplied to the pixel,
          i.e. drive conditions.

Of these five parameters, the efficiency and half-life

are defined by the device/material properties and cannot be
altered. The other parameters however can be altered. The
pixel area ratio can be modified for a display, but cannot
be changed during operation. For a certain device
5 construction a common cathode and anode could be chosen,
this will lead to an identical voltage across pixels with
different colours. The pulse width ratio can be changed
during operation by the driver circuit. In Table 2, an
overview is given how the perceived luminance, display life
10 time, display efficiency and common voltage can be
optimised towards area ratio and pulse width.

In theory, therefore, there are five different
optimised operational regimes which may be summarised as:

1.1 Equal (perceived) luminance, different voltage,
15   different efficiency, equal half-life;

1.2 Equal (perceived) luminance, equal voltage, different
       efficiency, different half-life;

1.3 Equal (perceived) luminance, different voltage,
       optimal efficiency, different half-life;

20 1.4 Different (perceived) luminance, equal voltage,
       different efficiency, equal half-life; and

1.5 Different (perceived) luminance, different voltage,
       optimal efficiency, equal half-life.

        1.1 Equal luminance, different voltage, different
25   efficiency, equal half-life

For an ideal three-colour display all the display area
can be used for the pixels. In a standard display, all the
pixels have the same area and therefore 1/3 of the display

area is available for each colour. If a display should
have a luminance for each colour of e.g., 100 cd/m^2, a pixel
luminance of 300 cd/m^2 per pixel is required. In the
example of Figure 5, the display lifetime is controlled by
5 the lowest half-life and is in this example 333 hrs. The
overall display lifetime can be increased, say to 800 hrs,
by optimising the pixels' areas. [In the example of Figure
5, it is assumed that the initial luminance multiplied with
the half-life is constant]. However, the optimisation can
10 also be done for other relationships. In order for the
perceived luminance to be 100 cd/m^2/(pixel area ratio). From
Figure 5, the luminance values needed for the blue green
and red pixels are 125, 625 and 2500 cd/m^2 in order to
obtain identical half-lives. Therefore the relative pixel
15 area ratios are . A(blue): A(green): A(red) = 100/125
:100/625 : 100/2500 i.e., 0.8 : 0.16 : 0.04 instead of
1/3:1/3:1/3.

1.2. Equal luminance, equal voltage, different
efficiency, different half-life.

20 In some display applications, a common pixel voltage
might be needed for instance in the case of a common anode
and cathode e.g., to produce a cheap white backlight.
Suppose, for example, luminance voltage curves are as shown
in Figure 6. By driving all the pixels at an identical
25 voltage of 4V, each different coloured pixel will have a
different luminance. In order to obtain uniform perceived
luminance three options are available:

1. Optimise relative pixel areas.

The relative pixel areas can now be optimised for the perceived brightness to be identical for each colour.

$$Lum_{perceived} = Lum_{pixel}.Relative\_pixel\_area$$

For a uniform perceived luminance the relative pixels areas should be $A(blue):A(green):A(red) = 1/85 : 1/200 : 1/3666 = 0.691 : 0.293 : 0.016$ (since sum of area ratios must equal unity) resulting in a 58.7 cd/m^2 perceived luminance for each colour. The disadvantage of this solution is, that for each required display luminance another pixel area ratio is required. The next solution overcomes this problem.

2. <u>Optimise pixel driving time.</u>

The luminance of a pixel can also be controlled by adjusting the driving pulse width of a pixel. The ratio of the pulse width for the blue, green and red pixel are identical to point 1. This solution has the advantage, that the pulse width can be adjusted if another display luminance is required.

3. <u>Optimise both driving time and pixel area.</u>

Both solutions mentioned above can be combined. Choose an appropriate pixel area ratio resulting in very similar pulse width. This avoids the need of high frequency pulses, which can result in worse performance and higher driver IC design and fabrication costs.

1.3. <u>Equal luminance, different voltage, optimal efficiency, different half-life.</u>

The display can also be optimised towards equal

luminance and optimal efficiency per colour. In this example, the power losses due to pulsed driving are neglected. As can be seen from Figure 7 each colour has an optimal efficiency at a different luminance. The perceived
5 luminance may be made equal by adjusting the ratio of pixel areas and/or the pulse widths.

1.   Optimise relative pixel areas

In order for the perceived brightnesses to be equal, the pixel area ratios should be the inverse of the
10 luminance ratios or A(blue):A(green):A(red) = 1/100 : 1/75 : 1/10 = 0.081 : 0.108 : 0.811. This will lead to a perceived luminance of 8.1 cd/m^2. Lower luminance values can be achieved at optimal efficiency by changing the pulse width, although AC driving results in extra power loss. The
15 optimal efficiency cannot be achieved for higher luminance values.

1.4 Different luminance, equal voltage, different efficiency, equal life-time.

In some applications a different perceived luminance
20 of the different pixel colours can be acceptable, e.g., in communication applications. The pixel area ratio cannot be used to equalise the half-lives at an identical pixel voltage, since with the pixel area only the perceived luminance can be modified. However, the pulse width ratio
25 can be used to allow identical pixel voltage and identical half lives for the different pixels. An equal voltage, e.g., 4V, for all the colours and an equal life time for these colours can be achieved by changing the pulse width.

In this example, figure 8 gives the half-lives for the different colours at 4V as $T_{1/2}(\text{red})=10000$ hrs, $T_{1/2}(\text{green})=120$ hrs and $T_{1/2}(\text{blue})=1000$ hrs. By choosing pulse widths inversely proportional to the half-lives, identical life times are attainable, i.e., width(red) : width(green) : width(blue) = 1 : 0.012 : 0.1. The luminance of the pixels will not be equal and are in this example:

$\text{Lum(red)} = 200*1 = 200 \text{ cd/m}^2$;

$\text{Lum(green)} = 4000*.0.012 = 48 \text{ cd/m}^2$; and

$\text{Lum(blue)} = 100*.0.1 = 10 \text{ cd/m}^2$.

1.5 <u>Different luminance, different voltage, optimal efficiency, equal life-time.</u>

Another solution is to optimise the pulse width in order to achieve maximal efficiency for all the colours and an equal half-life for all the colours. From Figure 9, it can be seen that operating at the optimal efficiency values (see figure 7) for red green and blue gives half-lives of 50,000 hrs, 10,000 hrs and 2,000 hrs respectively. In order to obtain equal life times the pixels can be pulse-driven, leading of course to different luminances. In this example a pulse width ratio of: width (red): width (green): width(blue) = 1 : 0.2 : 0.04 will lead to an overall half life of 50,000 hrs, however the corresponding luminance values are:

$\text{Lum(red)} = 40 \text{ cd/m}^2$;

$\text{Lum(green)} = 10 \text{ cd/m}^2$; and

$\text{Lum(blue)} = 2 \text{ cd/m}^2$.

Figure 10 shows part of a graphic display 10
incorporating a light-emitting device 12 embodying at least
one aspect of the present invention. The light-emitting
device 12 includes polymer-based electroluminescent
5   elements 14, a first (14R) of which is able to emit red
light when energised, a second (14B) of which is able to
emit blue light when energised, and a third (14G) of which
is able to emit green light when energised. The elements
14 are mounted on a transparent substrate 16 coated with
10 transparent electrodes (not shown) as in Figure 1. The
active lifetimes of and voltage drive characteristics for
the three different elements are set out in Table 1.

The "red" element 14R is located centrally and the
"green" and "blue" elements 14G,14B, are located
15 symmetrically around it. Such peripheral elements of the
same colour are operated as one thus ensuring the colour
centroid is at the physical centre of the device. In this
example, the ratio of the areas covered by each of the
elements in the device 12 is approximately one-third red to
20 one green to three blue. (The area of the green element is
first selected, and then the areas of the red and blue
elements are decreased and increased respectively although
not necessarily optimised according to 1.1 or 1.2.). The
different coloured elements in the device may be configured
25 to operate at a common potential, or with different
potentials. Taking each scenario in turn;

Common Potential

At a common potential, (e.g. V_1) the brightness of

light emitted from each element when energised will vary
from colour to colour, being greatest for the red emitter
and lowest for the blue emitters. This follows from Figure
3 on the assumption that the "green" emitter falls in
5 between the extremes set by the "red" and "blue" emitters.
However, the amount of light produced of the three colours
will be approximately equal since total light emission is
also dependent on the area from which light is emitted.
Achieving even light emission for each colour is desirable
10 in graphic displays. The "common potential" approach
achieves this by increasing the area of the element(s) with
the lowest brightness relative to the area of the element
with the highest brightness. This is quite distinct from
the use of equal areas and achieving a balance in
15 brightness by driving the "blue" element(s) at a higher
potential than the "red" element. As shown in Figure 2,
the higher the brightness emitted by an organic
electroluminescent element, the shorter the service life.
Thus, by achieving a balance in light output using area
20 compensation instead of voltage compensation, the "blue"
element(s) may be operated at a lower brightness than the
"red" element to increase service life (e.g. from t_1 to t_2
in Figure 2).

Different Potential

25   In view of the disparity between voltage drive
characteristics of the "red", "green" and "blue" elements
(see Figure 3), it may be desirable to drive the "blue"
elements at a higher potential than the "red" and "green"

elements. However, driving the "blue" elements at a higher
potential would increase brightness, and would seem to
reduce active lifetime and hence service life, rather than
increase it.   Thus, it is necessary to pulse the potential
5 to the "blue" element such that even though producing an
equivalent light output to the other elements, the actual
time average brightness is lowered, thereby extending
active lifetime.   Of course, it would be possible to drive
all elements with pulsed potentials, in which case the
10 desired effect is achieved by pulsing different elements in
different ways.   For example, if pulsed with the same
frequency, the pulse width may be greater for "red"
elements than for the "blue" elements, as shown in Figure
6.   In this way, the service life of the graphic display
15 may be increased from 1.5K hours to 4.5K hours; a three-
fold improvement over the active lifetime of a blue element
operated in the conventional way.

TABLE 1

20

	Active Lifetime	Vol.Drive Charact.
Red Emitter	30K hours (good)	Low
Green Emitter	10K hours (moderate)	Low
Blue Emitter	1.5K hours (short)	High

25

TABLE 2

	Equal Perceived Pixel Luminance	Half Life	Voltage/ current Pixel	Efficiency
Equal Perceived pixel Luminance	X	Area 1.1	Area, time 1.2	Area, Time 1.3
Half-Life		X	Time 1.4	Time 1.5
Voltage/current pixel			X	No solution
Efficiency				X

28

CLAIMS

1. A light-emitting device comprising: a first electroluminescent element for emitting light of a first colour when energised; and a second electroluminescent
5 element for emitting light of a second colour when energised, the first electroluminescent element having an active lifetime which is greater than that of the second electroluminescent element; characterised in that the second element is configured to operate at a lower
10 brightness than the first element.

2. A light-emitting device according to claim 1, in which the first or second electroluminescent elements comprise organic light emissive material.

3. A light-emitting device according to claim 2, in which
15 the organic light emissive material is polymeric.

4. A light-emitting device according to any one of claims 1 to 3, in which the first and second electroluminescent elements are energised by a common potential.

5. A light-emitting device according to claim 4, in which
20 the common potential is applied through an electrode common to both elements.

6. A light-emitting device according to claim 5, in which the common potential is applied between an anode and a cathode common to both elements.

25 7. A light-emitting device according to any one of claims 1 to 6, in which the first and second electroluminescent elements are energised by different potentials.

8. A light-emitting device according to claim 7, in which

the second electroluminescent element is energised at a higher potential than·the first electroluminescent element.

9.   A light-emitting device according to claim 4,5,7 or 8, in which the potential applied to one or both of the 5 electroluminescent elements is pulsed.

10.   A light-emitting device according to claim 9, in which the first electroluminescent element is energised for longer periods than the second electroluminescent element.

11.   A light-emitting device according to claim 10, in 10 which the first electroluminescent element is pulsed more frequently or with a greater pulse width than the second electroluminescent element.

12.   A light-emitting device according to any one of claims 9 to 11, in which over a given period the ratio between 15 energization times for the first and second electroluminescent elements is substantially equal to the ratio between the lifetimes of the second and first electroluminescent elements respectively.

13.   A light-emitting device according to any one of the 20 preceding claims, in which the second element is adapted to emit light over a larger area than the first element.

14.   A light-emitting device according to claim 13, in which the ratio between the light-emitting areas of the first and second electroluminescent elements is 25 substantially equal to the ratio between the brightness of the second electroluminescent element and the brightness of the first electroluminescent element when energised for equal periods.

15. A light-emitting device according to any one of claims 1 to 14, in which the first and second colours of light emission are selected from the group consisting of red, green and blue.

5   16. A light-emitting device according to any one of the preceding claims, in which the ratio between the brightness of the first electroluminescent element and the brightness of the second electroluminescent element is substantially equal to the ratio between the active lifetime of the first 10 electroluminescent element and the active lifetime of the second electroluminescent element.

17. A light-emitting device according to any one of claims 1 to 16, further comprising a third electroluminescent element for emitting light of a third colour when 15 energised, the third electroluminescent element having an active lifetime in between that of the first and second electroluminescent elements.

18. A light-emitting device according to claim 17, in which the third electroluminescent element is energised by 20 the same potential as the first electroluminescent element.

19. A light-emitting device according to claim 17 or 18 when appendent to claim 13, in which the third electroluminescent element is adapted to emit light over an area which is greater than that of the first 25 electroluminescent element but less than that of the second electroluminescent element.

20. A graphic display comprising a light emitting device according to any one of claims 1 to 19, wherein each

electroluminescent element corresponds to a pixel for displaying graphic information.

21. A light-emitting device substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

22. A light-emitting device, comprising: a first electroluminescent element for emitting light of a first brightness when energised by a predetermined potential; and a second electroluminescent element for emitting light of a second brightness when energised by the predetermined potential, the second brightness being less than the first brightness; characterised by means for energising the first and second electroluminescent elements at the predetermined potential, and in that the second electroluminescent element has a larger light-emitting area than the first electroluminescent element.

23. A light-emitting device according to claim 22, in which the first or second electroluminescent elements comprise an organic light emissive material.

24. A light-emitting device according to claim 23, in which the organic light emissive material is polymeric.

25. A light-emitting device according to any one of claims 22 to 24, in which the energising means comprises at least one electrode common to both electroluminescent elements.

26. A light-emitting device according to claim 25, in which the energising means comprises an anode and a cathode, each common to both electroluminescent elements.

27. A light-emitting device according to any one of claims

22 to 26, in which total light emitted by the first electroluminescent element is substantially equal to total light emitted by the second electroluminescent element in any given time interval when both electroluminescent
5 elements are energised.

28. A light-emitting device according to any one of claims 22 to 27, in which the ratio of the first brightness to the second brightness is substantially equal to the ratio of the light-emitting area of the second electroluminescent
10 element to the light-emitting area of the first electroluminescent element.

29. A light-emitting device according to any one of claims 22 to 28, in which the first and second electroluminescent elements emit light of first and second colours
15 respectively when energised, the first and second colours being selected from the group consisting of red, green and blue.

30. A light-emitting device according to any one of claims 22 to 29, further comprising: a third electroluminescent
20 element for emitting light of a third brightness when energised by the predetermined potential, the third brightness being in between that of the first and second brightnesses; and means for energising the third electroluminescent element at the predetermined potential.

25 31. A light-emitting device according to claim 30, in which the third electroluminescent element has a light-emitting area greater than that of the first element and less than that of the second element.

32. A graphic display comprising a light-emitting device according to any one of claims 22 to 31, wherein each electroluminescent element corresponds to a pixel for displaying graphic information.

33. A light-emitting device comprising: a first electroluminescent element for emitting light of a first colour when energized; and a second electroluminescent element for emitting light of second colour when energized, the first electroluminescent element emitting light at a lower luminance than that of the second electroluminescent element when each is energized with optimal efficiency; characterized in that the first and second electroluminescent elements are configured to operate at the same perceived brightness when both electroluminescent elements are energized with optimal efficiency.

34. A light-emitting device according to claim 33, in which the first or second electroluminescent elements comprise organic light emissive material.

35. A light-emitting device according to claim 34, in which the organic light emissive material is polymeric.

36. A life-emitting device according to any one of claims 33 to 35, in which the first and second electroluminescent elements are energized by a common potential.

37. A light-emitting device according to any one of claims 33 to 35, in which the first and second electroluminescent elements are energized by different potentials.

38. A light-emitting device according to claim 37, in which the second electroluminescent element is energized at

a higher potential than the first electroluminescent element.

39. A light-emitting device according to claim 36,37 or 38, in which the potential applied to one or both of the electroluminescent elements is pulsed.

40. A light-emitting device according to claim 39, in which the first electroluminescent element is energized for longer periods than the second electroluminescent element.

41. A light-emitting device according to claim 40, in which the first electroluminescent element is pulsed more frequently or with a greater pulse width than the second electroluminescent element.

42. A light-emitting device according to any one of claims 33 to 41, in which the first electroluminescent element is configured to emit light over a larger area than the second electroluminescent element.

43. A light-emitting device according to claim 42, in which the ratio between the light-emitting areas of the first and second electroluminescent elements is substantially equal to the ratio between the luminances of the second and first electroluminescent elements respectively when energized with optimal efficiency.

44. A light-emitting device according to any one of claims 33 to 43, in which the first and second colours of light emission are selected from the group consisting of red, green and blue.

45. A light-emitting device according to any one of claims 33 to 44, further comprising a third electroluminescent

element for emitting light of a third colour when energized, the third electroluminescent element emitting light at a luminance in between that of the first and second electroluminescent elements when energized with

5 optimal efficiency.

46. A graphic display comprising a light-emitting device according to any one of claims 33 to 45, wherein each electroluminescent element corresponds to a pixel for displaying graphic information.

10 47. A light-emitting device comprising: a first electroluminescent element for emitting light of a first colour when energized; and a second electroluminescent element for emitting light of a second colour when energized, the first electroluminescent having a half-life

15 which is greater than that of the second electroluminescent element when each is energized with optimal efficiency; characterized in that the second electroluminescent element is configured to operate at a lower brightness than the first electroluminescent element when both are energized

20 with optimal efficiency.

48. A light-emitting device according to claim 47, in which the first or second electroluminescent elements comprise organic light emissive material.

49. A light-emitting device according to claim 48, in

25 which the organic light emissive material is polymeric.

50. A life-emitting device according to any one of claims 47 to 49, in which the first and second electroluminescent elements are energized by a common potential.

51. A light-emitting device according to any one of claims 47 to 49, in which the first and second electroluminescent elements are energized by different potentials.

52. A light-emitting device according to claim 51, in
5 which the second electroluminescent element is energized at a higher potential than the first electroluminescent element.

53. A light-emitting device according to claim 50,51 or 52, in which the potential applied to one or both of the
10 electroluminescent elements is pulsed.

54. A light-emitting device according to claim 53, in which the first electroluminescent element is energized for longer periods than the second electroluminescent element.

55. A light-emitting device according to claim 54, in
15 which the first electroluminescent element is pulsed more frequently or with a greater pulse width than the second electroluminescent element.

56. A light-emitting device according to any one of claims 47 to 55, in which the first electroluminescent element is
20 configured to emit light over a larger area than the second electroluminescent element.

57. A light-emitting device according to claim 56, in which the ratio between the light-emitting areas of the first and second electroluminescent elements is
25 substantially equal to the ratio between the brightness of the second and first electroluminescent elements respectively when energized with optimal efficiency.

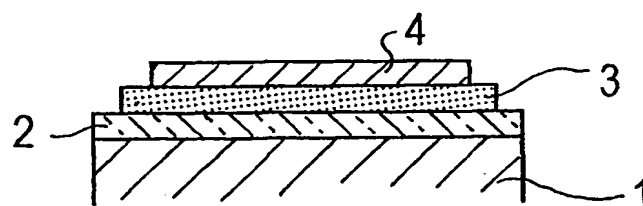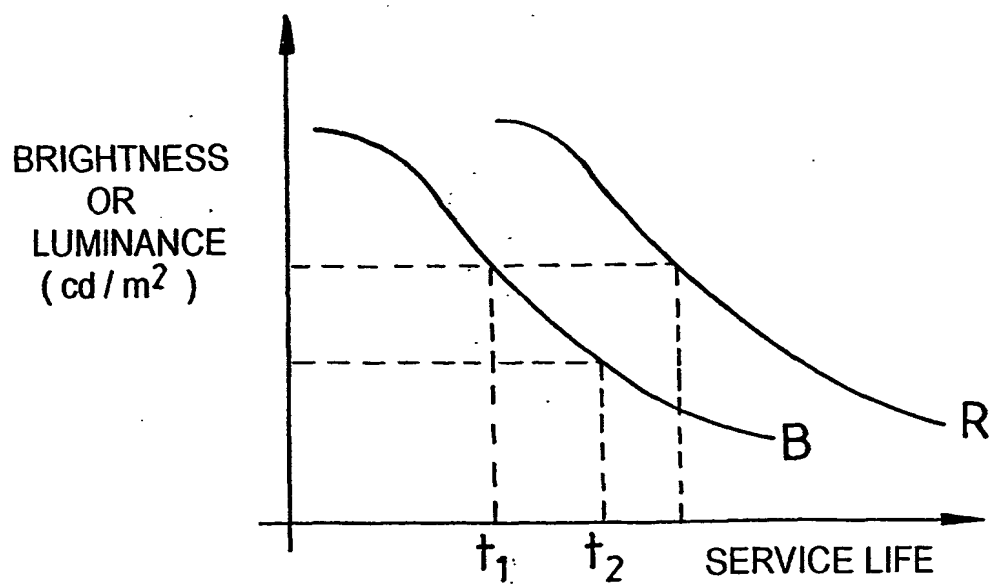58. A light-emitting device according to any one of claims

47 to 57, in which the first and second colours of light emission are selected from the group consisting of red, green and blue.

59. A light-emitting device according to any one of claims 47 to 58, further comprising a third electroluminescent element for emitting light of a third colour when energized, the third electroluminescent element emitting light at a luminance in between that of the first and second electroluminescent elements when energized with optimal efficiency.
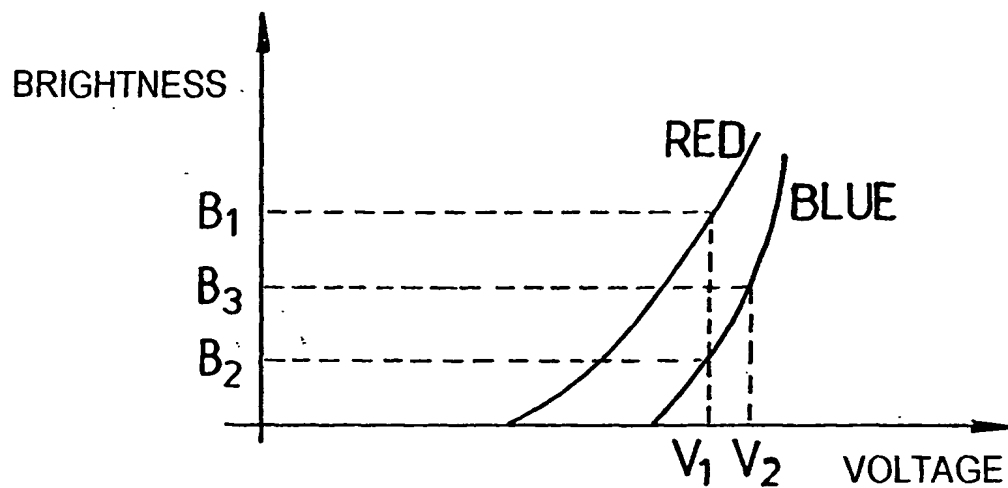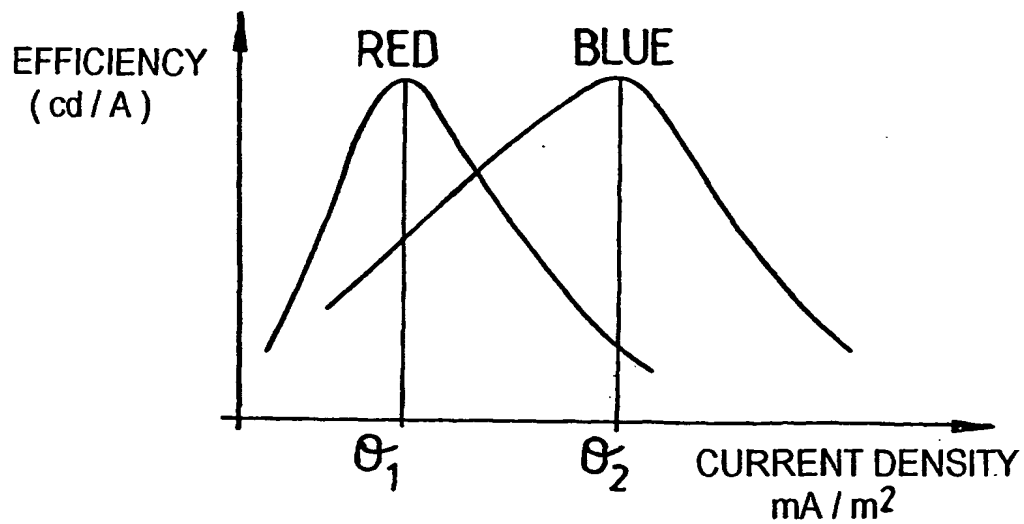
60. A graphic display comprising a light-emitting device according to any one of claims 47 to 59, wherein each electroluminescent element corresponds to a pixel for displaying graphic information.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

3 / 7

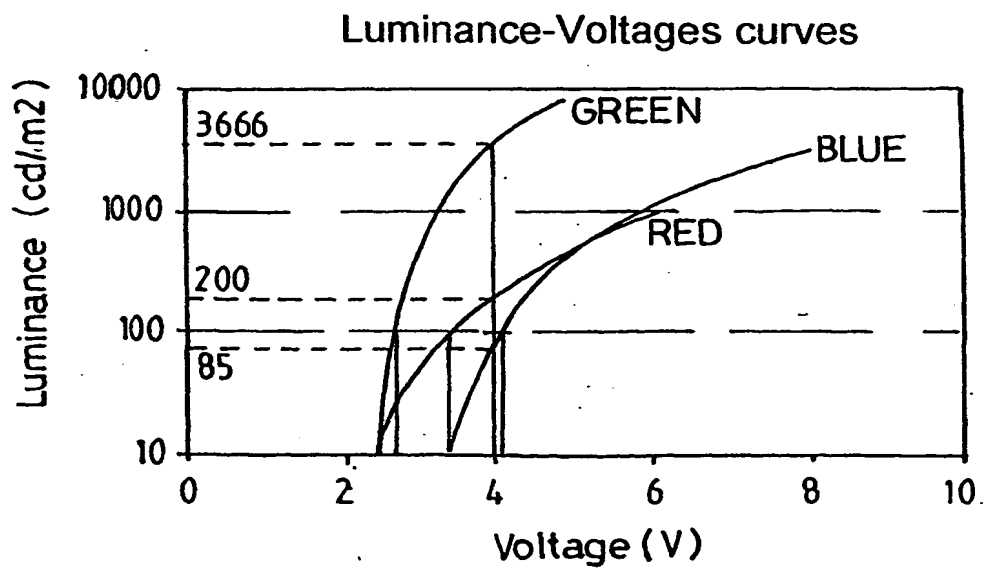## Half life vs initial luminance

Fig. 5

Luminance-Voltages curves

Fig. 6

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Efficiency curves

Fig. 7

Half life vs Pixel voltage

Fig. 8

Fig. 9

Fig. 10

Fig. 11

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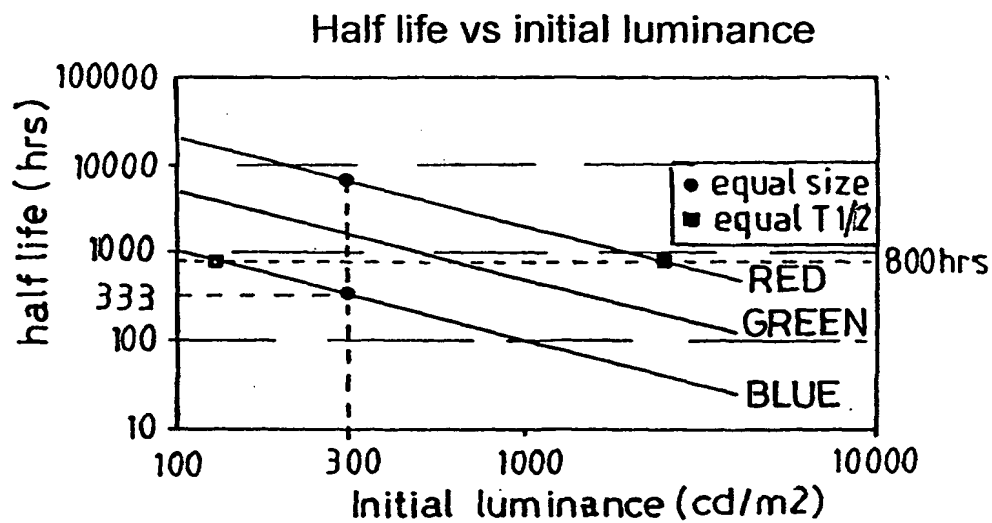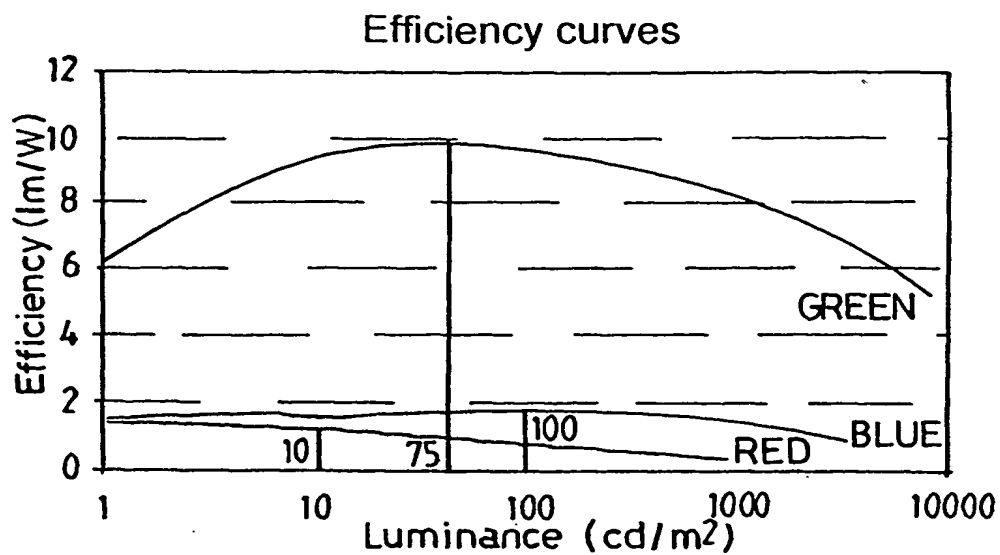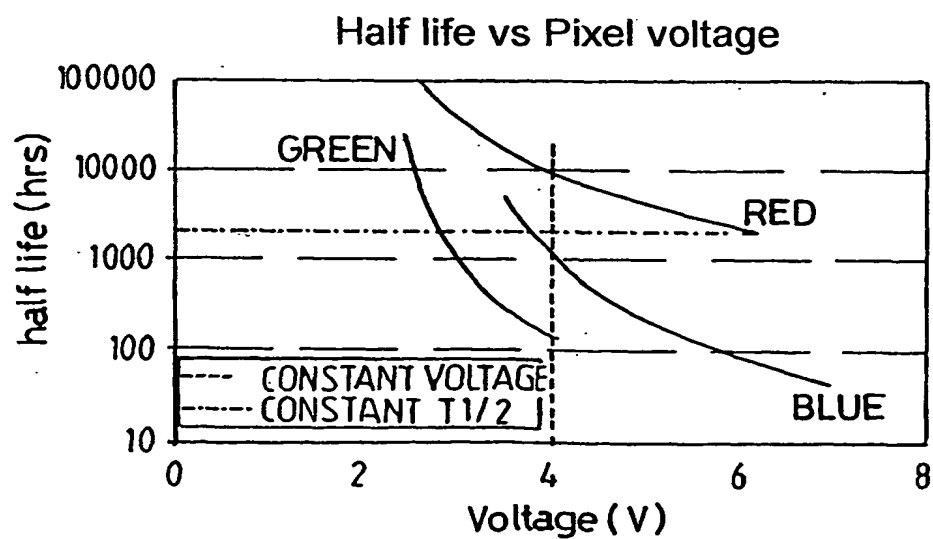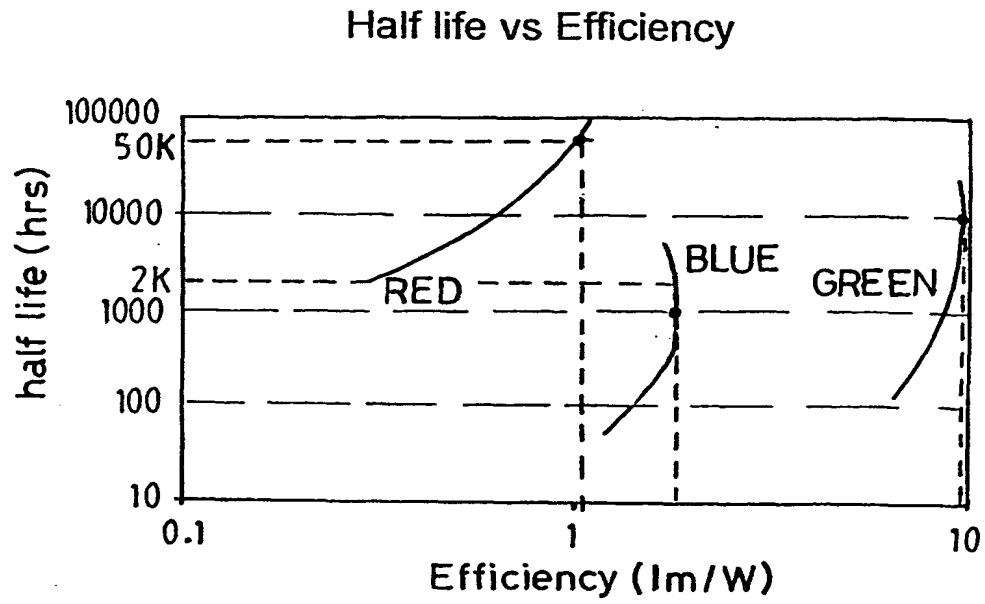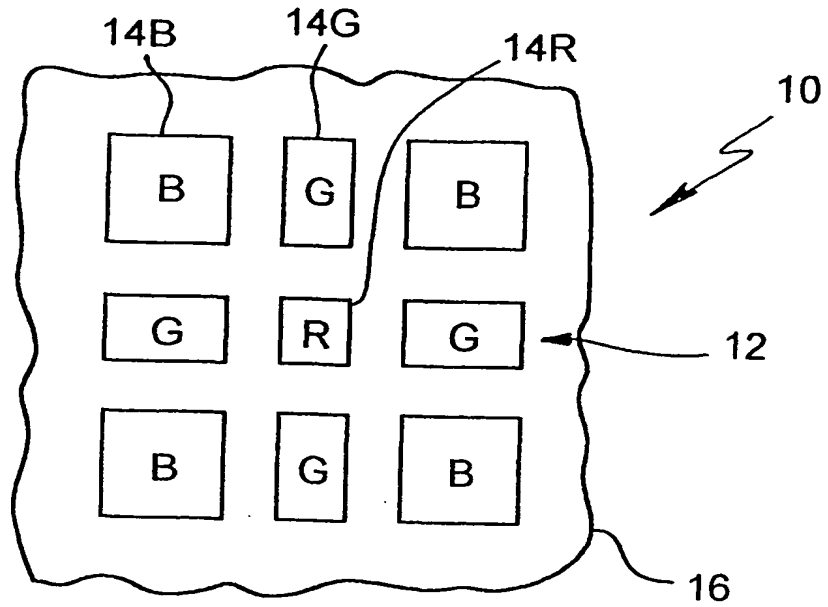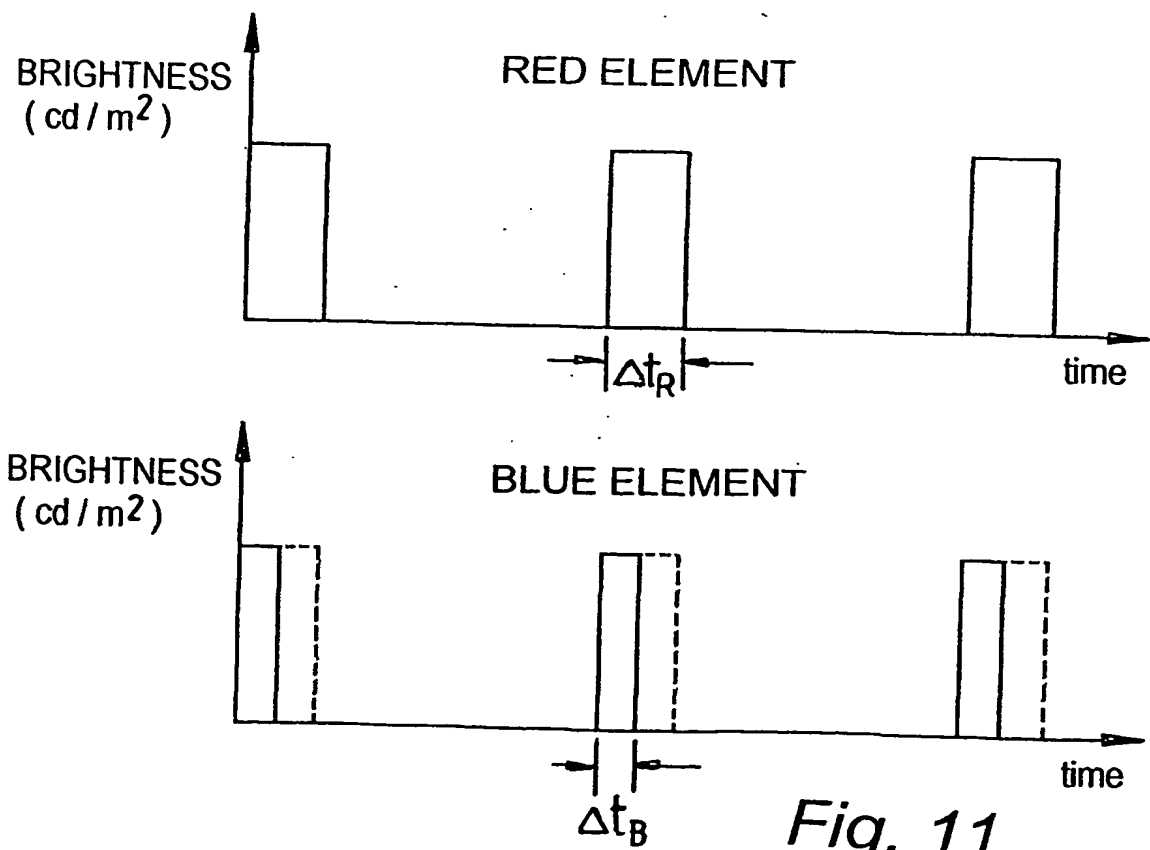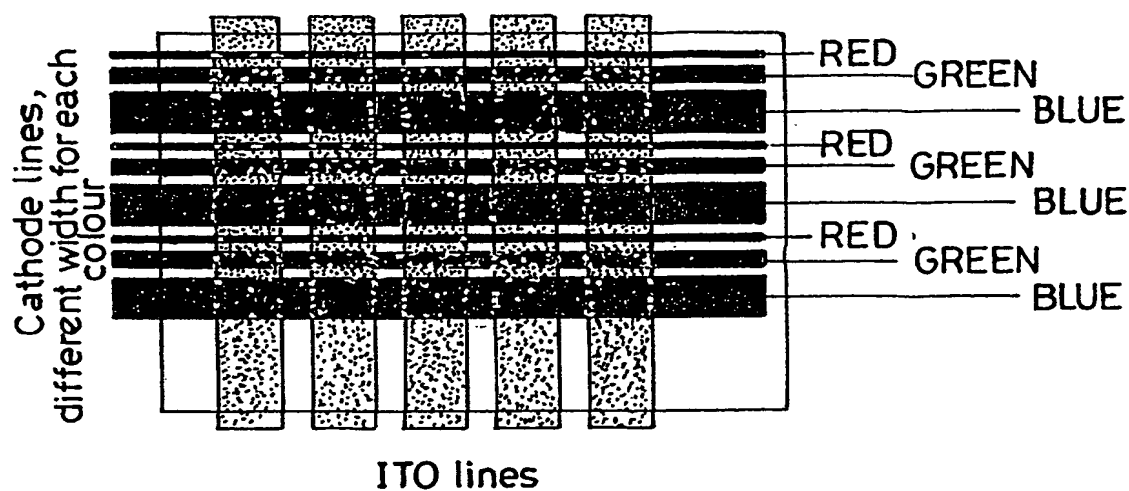
Fig. 12
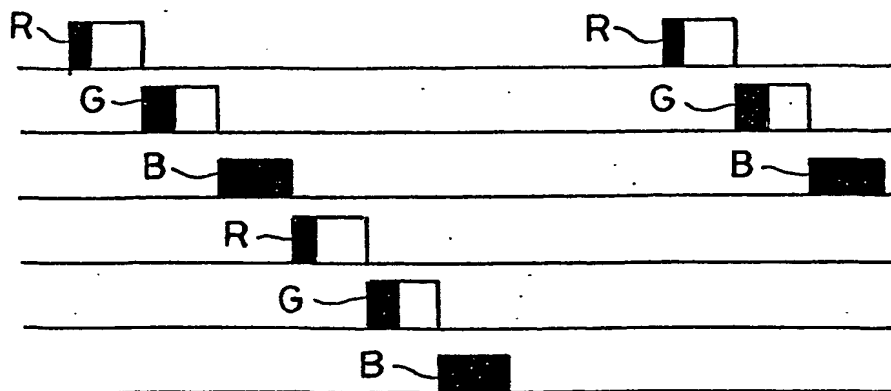
Fig. 13

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7   H01L27/15

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   H01L   G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 06, 30 April 1998 (1998-04-30) -& JP 10 039791 A (MITSUBISHI ELECTRIC CORP;IDEMITSU KOSAN CO LTD), 13 February 1998 (1998-02-13) abstract	1,2,4,5, 7,9-23, 25,27-32
A		3,6,8, 24,26, 33-60
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 09, 30 July 1999 (1999-07-30) -& JP 11 111457 A (SHARP CORP), 23 April 1999 (1999-04-23) abstract	1,2,4,5, 13, 17-23, 25,29-32

-/--

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 August 2001	21/08/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	De Laere, A

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INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A		1,33,47
A	WO 99 42983 A (BURROUGHES JEREMY HENLEY ;CAMBRIDGE DISPLAY TECH (GB); FRIEND RICH) 26 August 1999 (1999-08-26) the whole document	1-60
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P,A		25-28, 30-32

INTERNATIONAL SEARCH REPORT

Information on patent family members

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JP 11111457	A	23-04-1999	NONE		
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			CN	1291321 T	11-04-2001
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